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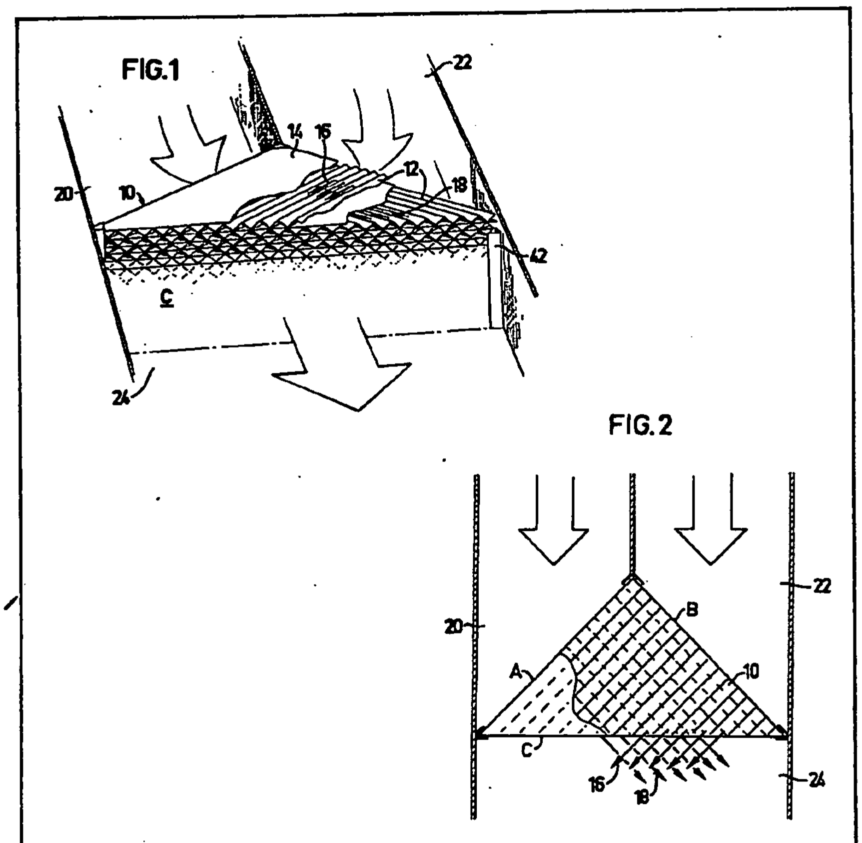
(54) Static mixers

(57) In the mixing of flowing media, such as gases, liquids, etc., the media are introduced into a mixing device separately and are mixed as they flow out of it. The mixing device (10, 10a) has at least two systems of separate channels each running from its respective inlet surface (A, B) and extending towards and discharging from a common outlet face (C) of the mixing device. The channels run at an angle to each other such that the media flowing from the two inlet faces (A, B) are essentially evenly distributed over the surface of the outlet face (C).



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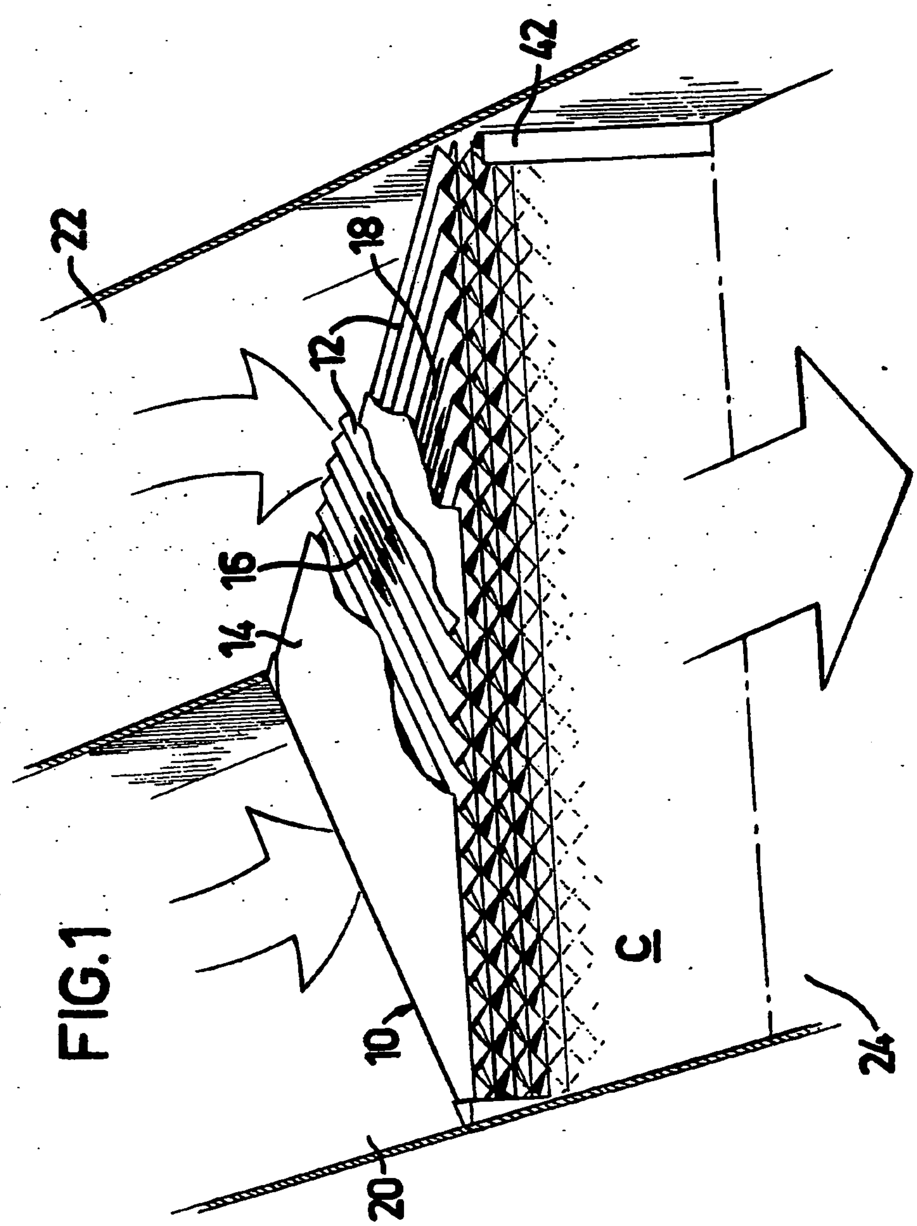

FIG.1

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FIG. 2

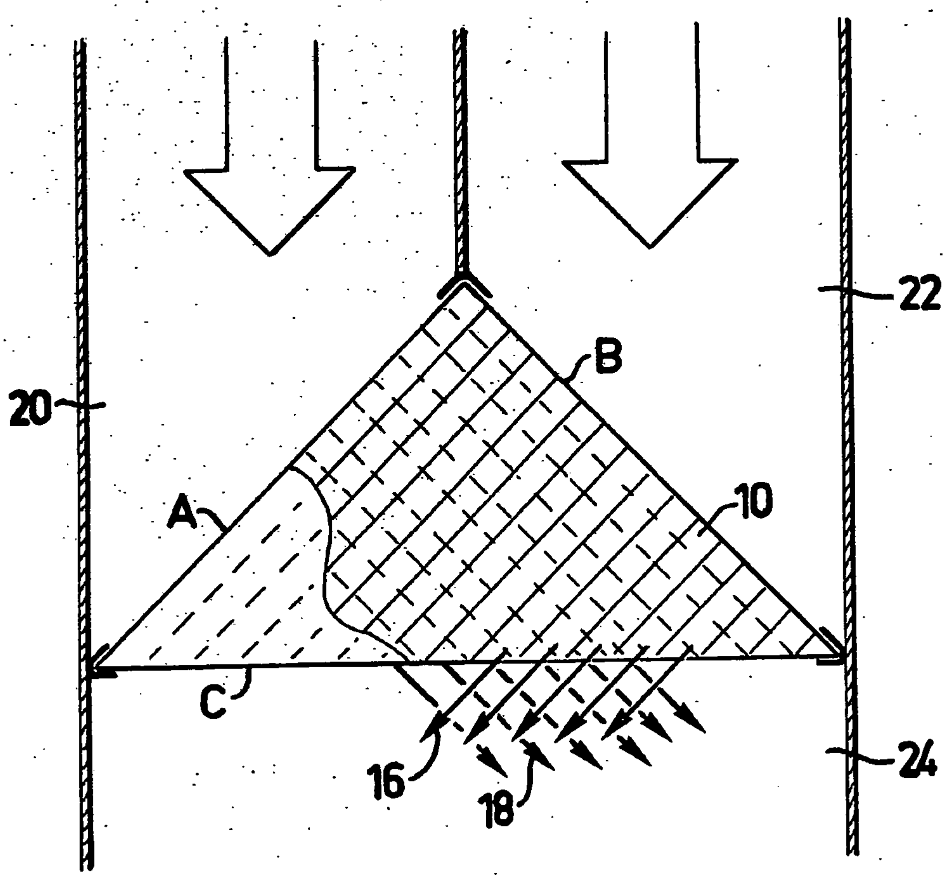

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FIG. 3

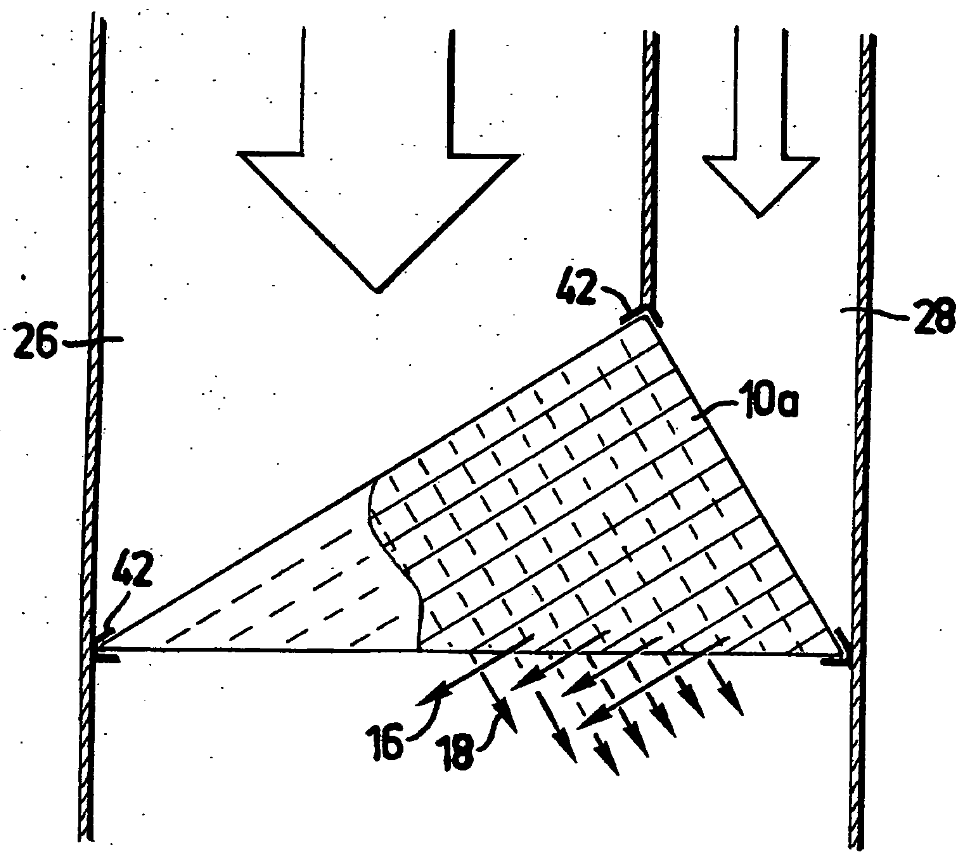
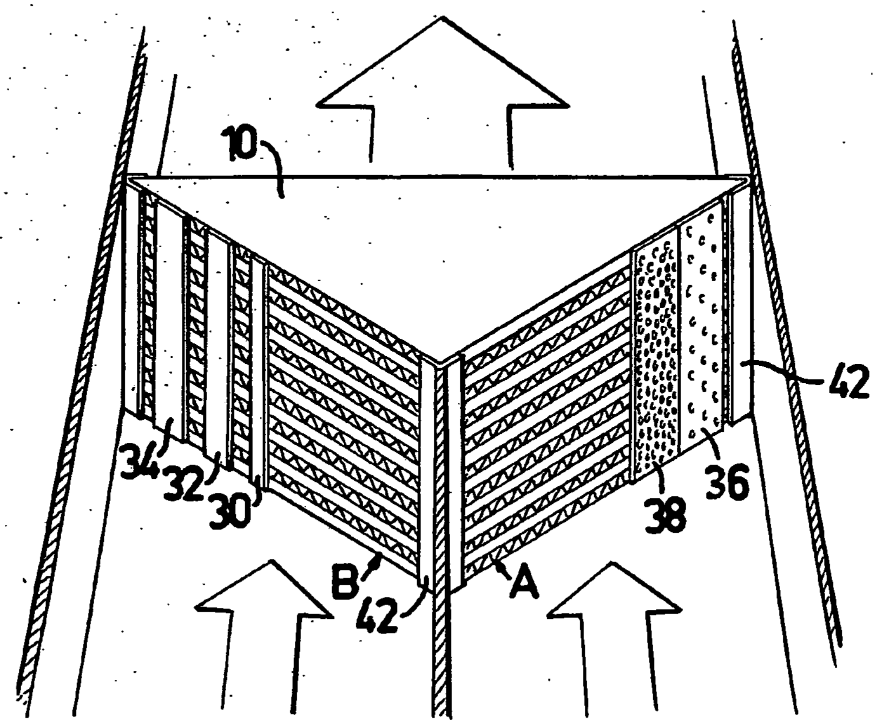


FIG. 4



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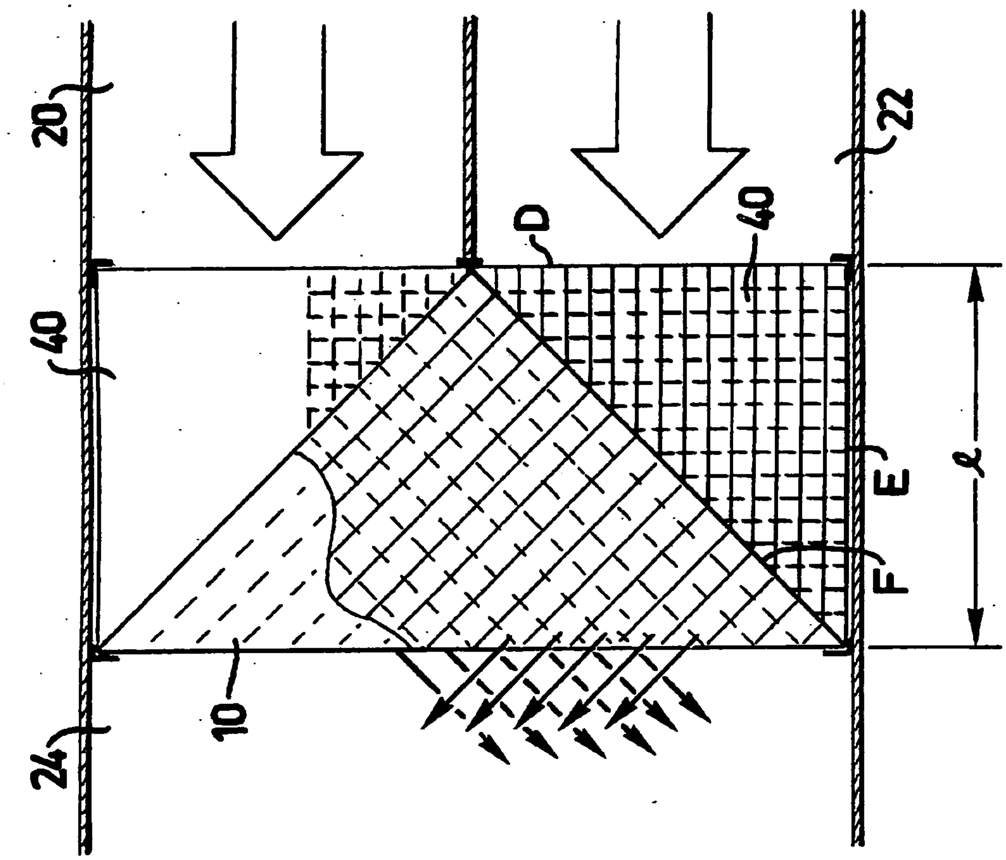

FIG.5

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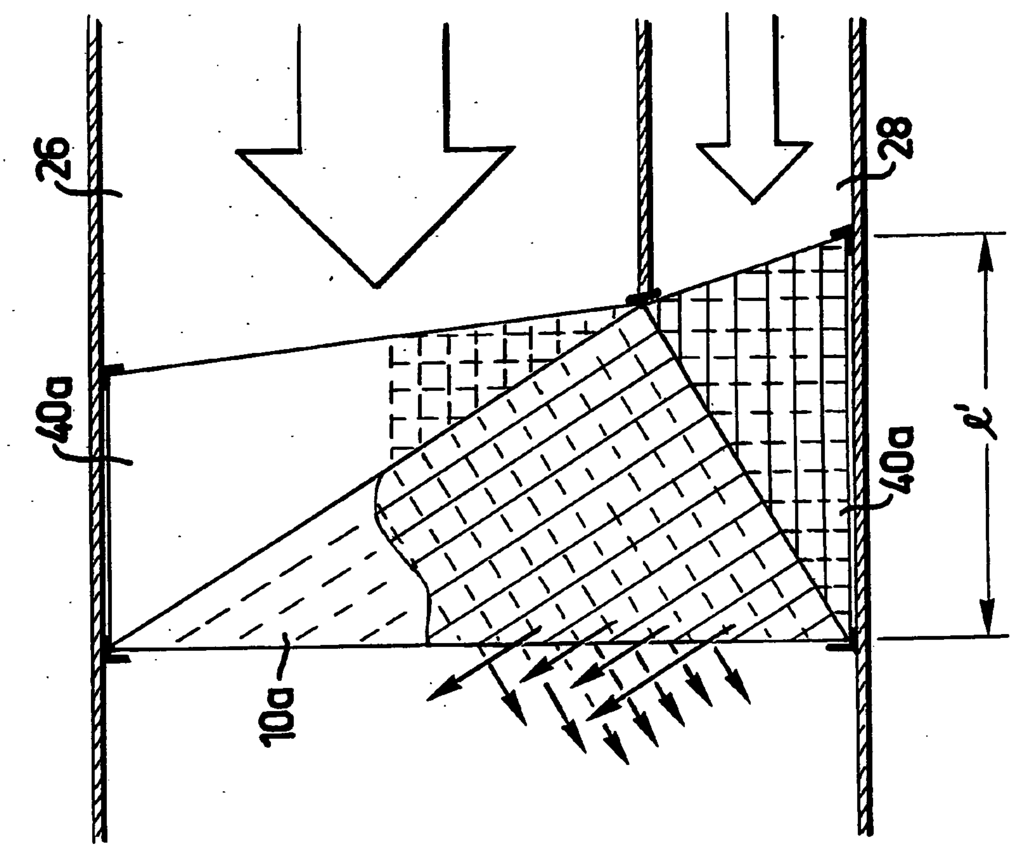


FIG.6

FIG. 7a

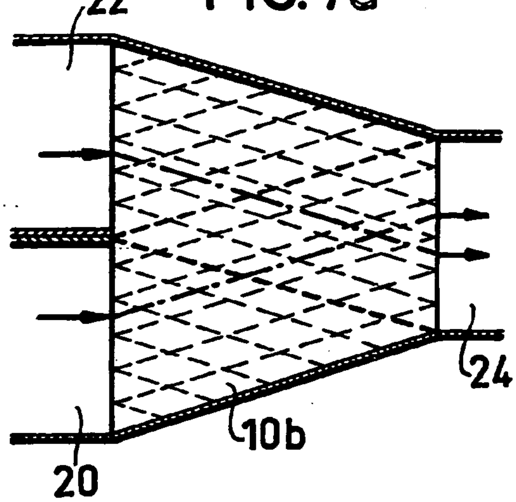


FIG. 7b

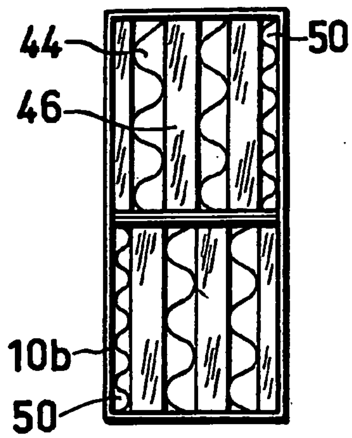


FIG. 7c

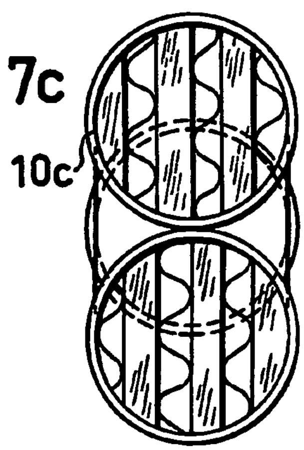


FIG. 8a

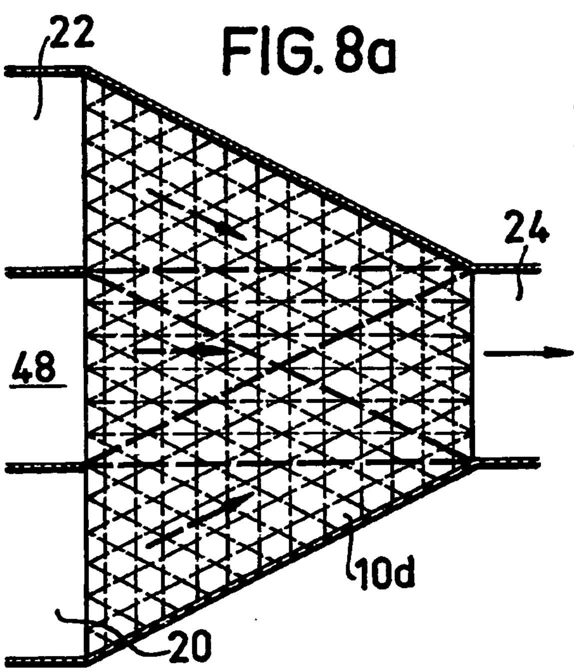


FIG. 8b

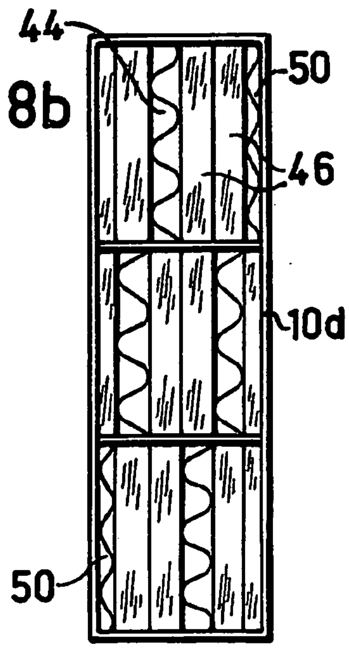


FIG.9

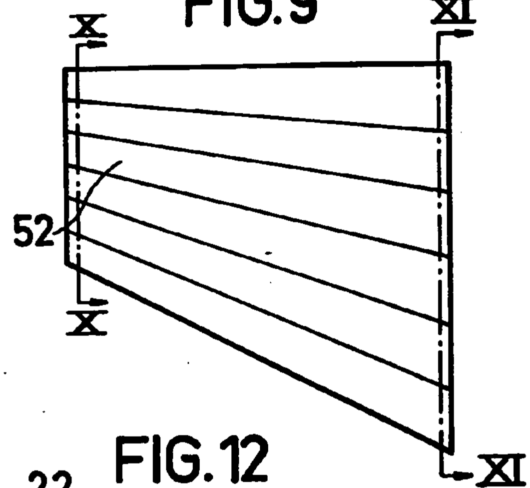


FIG.10

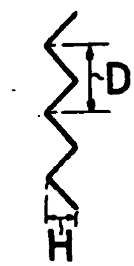


FIG.11

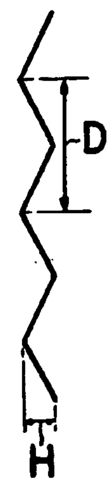
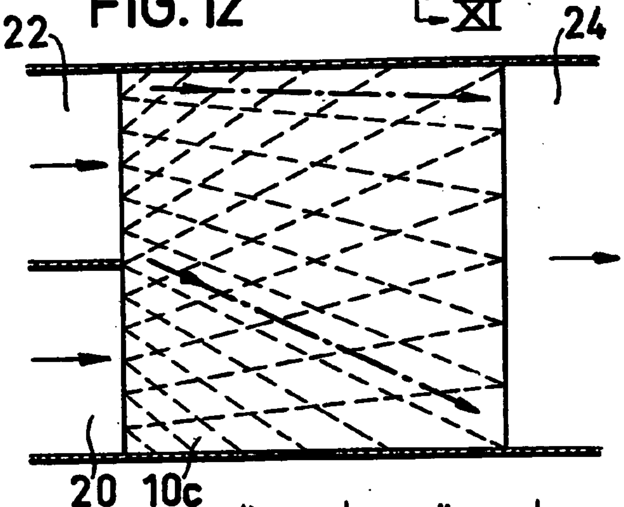


FIG. 12



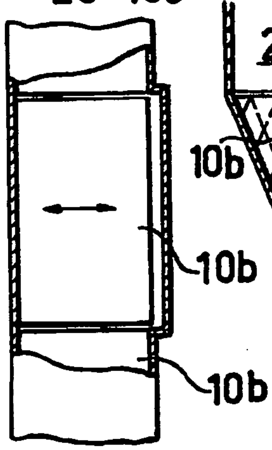


FIG.14b

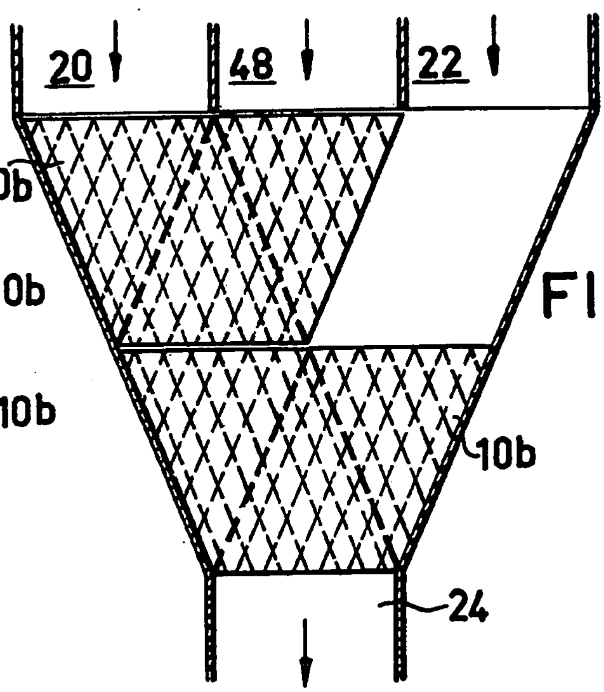
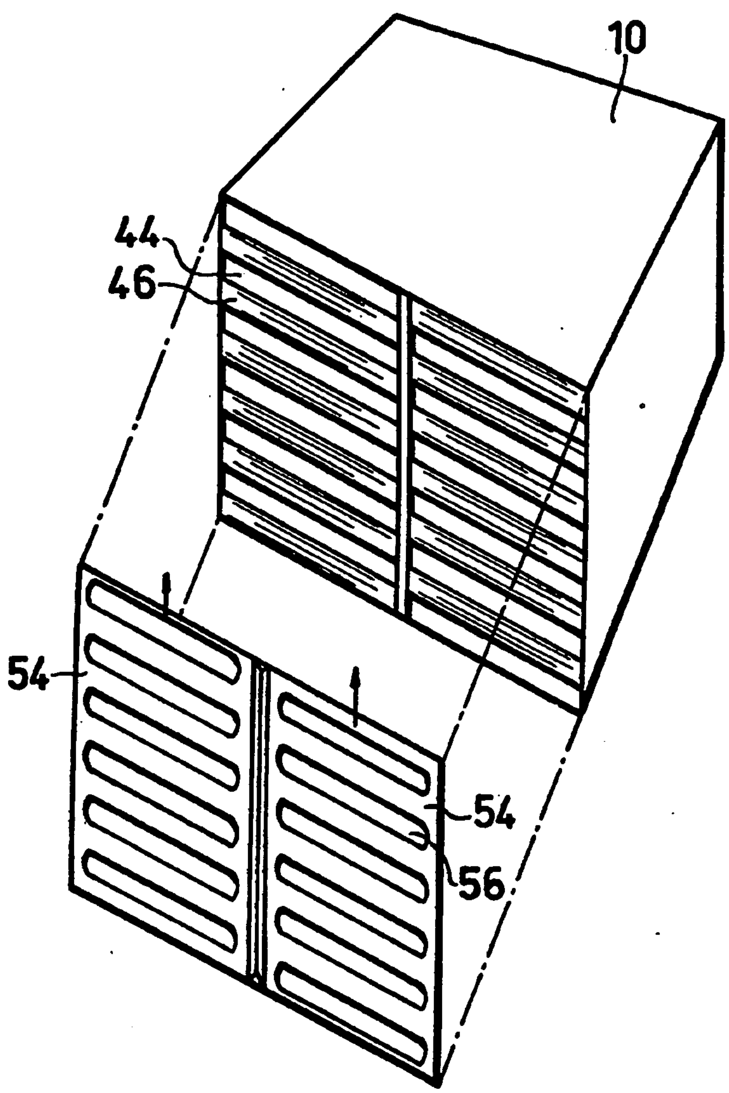


FIG.14a

FIG. 13



SPECIFICATION

Mixing device

The present invention concerns a mixing device for mixing flowing media, such as gases or liquids, in which the media are introduced into the mixing device separately and are mixed as they flow out of it.

In many industrial applications it is necessary to mix flowing media such as gases and/or liquids, e.g. for the purpose of equalizing temperatures, degrees of concentration and the like, and it is therefore known in chemical processing industries to use static mixers to even out the concentrations of various media. In ventilating plants in which a heater battery, for example, is supplied with cold outside air and warm return air, a static mixer may be used to mix the currents of air before they enter the heater battery and so bring about equalization of temperature so as to prevent uneven loading and hinder battery breakdown through freezing.

The most common type of mixing device designed for the purposes outlined above consists of an apparatus into which the media to be mixed are introduced separately, the actual mixing taking place within the apparatus itself. The disadvantage of mixers of this type is that the drop in pressure over the device is relatively great at the same time as the volume of the mixer itself must be large if the media are to be sufficiently well mixed before passing out of the apparatus.

A further method, used in burner apparatus for example, is to bring about the actual mixing of the media as they are expelled from the body of the burner by inducing turbulence in the media by various means, e.g. by baffles running helically inside the body of the burner. However, such arrangements are complicated in design and are therefore expensive to produce.

An object of the present invention is the provision of a simple, cheap mixing device in which the media are effectively and intimately mixed at the same time as the drop in pressure over the apparatus remains slight and the volume of the mixer itself is small.

According to the present invention there is provided a mixing device for mixing flowing media, such as gases, liquids, etc., in which the media are introduced into a mixing device separately and are mixed as they flow out of it, the mixing device comprising at least two systems of separate through channels which each runs from its respective inlet surface, extends towards and discharges from a common outlet face of the mixing device, such channels running at an angle to one another such that the media flowing from the two or more inlet faces are essentially evenly distributed over the surface of the outlet face.

The invention also includes a method of mixing two fluid media c mprising th st ps f passing a first fluid media through a first plurality of channels extending from a respective inlet t a common outlet in a mixing devic , passing the second fluid media through a second plurality of channels xtending from a respective inlet to the comm n outlet in the mixing device, and arranging the respective channels for the media so that the media are mixed as they flow out of the mixing device at the common outlet.

The invention will now be described by way of example with reference to the accompanying drawings. Figure 1 thus shows a schematic representation of a mixing device or apparatus in perspective constructed under the terms of the invention and mounted in a duct system. Figure 2 shows a plan view of the device of Figure 1. Figure 3 shows a plan view similar to that of Figure 2 but of a modified embodiment. Figure 4 is a perspective representation of a mixing device comprising a throttling device for regulating the flow through the apparatus. Figure 5 shows a plan view of a mixing apparatus provided with a pressure-compensating device. Figure 6 shows a modified version of a device similar to that illustrated in Figure 5. Figures 7a-7c show a modified embodiment of a mixing device having flutes or channels of equal length. Figures 8a and 8b show a device for mixing three media. Figure 9 shows a plan of a sheet having conical corrugations for use in a mixing device constructed as per the invention. Figures 10 and 11 show respectively a section taken along the lines designated X-X and XI-XI in Figure 9. Figure 12 shows a plan view of a mixer built up of sheets of the type illustrated in Figure 9. Figure 13 shows a perspective of a mixer comprising a device for regulating the media. Figures 14a and 14b show mixing devices for regulating the proportion of a mix of three media.

The embodiment of the mixer 10 designed according to the principles of the invention and illustrated in Figures 1 and 2 comprises a number of basic units consisting of a corrugated sheet 12 bearing against a flat sheet 14 to form a "single-faced corrugated unit". Alternate basic or single-faced corrugated units 12, 14 are placed at an angle, eg at a right angle as illustrated in Figure 1, in relation to the adjacent basic or corrugated units 12, 14. The straight channels formed by the corrugations of the corrugated layers will thus extend alternately in two directions, at right angles to one another, throughout the entire thickness of the mixer 10 body, as indicated by the arrows designated 16 and 18 in Figures 1 and 2. Since the basic units of the mixer are preferably three-sided or triangular, as is best illustrated in Figure 2, the short sides of such triangle being at right angles to the corrugations of the corrugated layers, two systems of continuous, straight channels are obtained, the channels of each system running from their separate inlets, A and B, to pass through the mixer, the channels of one system remaining separate from the ther, to the discharge fac C of the device where their outlets are spread over a common surface, the outlets of each system being evenly distributed over th discharge face C f the mixer.

The drawings originally filed wer informal and the print here r produced is taken from a later filed formal copy.

In the embodiment illustrated in Figures 1 and 2, two separate supply ducts 20, 22 are connect d to the inlets, A and B, of the mixing device 10 for directing two currents of the media t be mixed int the mixing device 10, while a third duct 24 is provided to carry the mixed media away from the device. The direction of flow of the media is shown schematically in the Figures by means of arrows. Although the mixing device 10 may be used for mixing all flowing media such as liquids, gases, etc., for the sake of simplicity the description to follow will refer to the mixture of separate currents of air for e.g. equalization of temperature in ventilation systems.

The two currents of air 16, 18 shown in Figure 1 as passing through the two systems of channels in the mixing device 10 will, when they reach the common discharge area along the longest side of the triangular mixer body, be mixed as they leave the apparatus 10, as indicated by the arrows 16, 18 in Figure 2. Since the outlets of the channels are, as mentioned, evenly distributed across the entire discharge area of the mixer 10, both laterally and vertically, it is clear that the large number of narrow channels will produce thoroughly efficient mixing of the media, such as currents of air, in that each of the media, such as currents of air, are evenly distributed over the entire discharge area.

The basic body of the mixer 10 comprises alternate plane 14 and corrugated 12 layers bearing upon each other. A suitable material for the relatively thin layers thus formed is plastic, a mineral fibre material such as some fibre-glass material, a metallic material such as aluminium, stainless steel, etc., or other similar material depending on the environment in which the mixing device 10 is to be used. The corrugation height chosen should be relatively large so as to obtain only a small drop in pressure due to friction. A suitable method of constructing the mixing device 10 is to stack rectangular or square basic single-faced corrugated units upon each other until the desired body thickness is obtained, the units being united by gluing, welding or the like, after which the desired triangular shape is obtained by dividing the square or rectangular body diagonally so as to give at least two triangular mixing devices. Of course, a mixer body having a shape departing from the purely triangular with its three straight sides is also conceivable, and bodies triangular or otherwise may be produced by separately cutting each of the single-faced corrugated layers of which the body is built up.

In the embodiment of the mixing device 10a illustrated in Figure 3, the mixer is mounted in two supply ducts 26, 28 of different widths and is no longer of symmetrical triangular shape, but each of its shorter sides is of different length so as to accommodate the different widths of the ducts.

As is apparent from Figures 2 and 3, the length of the straight channels running from inlet A or B to outlet C varies, depending on whether th channel in question begins at the right-angled corn r of the mixing device 10, 10a or runs closer to one of its pointed corners. This differenc in length may give rise to a certain variati n in the pressure drop over various parts of the mixer 10, 10a which may, in turn, cause some imbalance in the mixed current f air fl wing ut through th discharge face C f th mixer.

The invention pr vides for several meth ds of solving this problem. As illustrated in the left-hand section of Figure 4, slats 30, 32, 34 are attached to the mixer 10 at its pointed corner and cover some of the channel openings on the inlet side B. By this means, the current of air flowing in through the pointed corners of the device, i.e. where the channels are shortest, will be throttled and so effect a balance in the amount of air flowing through the body of the mixer. Approximately the same amount of air will thus pass out of the mixer evenly distributed over the discharge surface C. As illustrated in Figure 4, the slat 34 located closest to the pointed corner of the mixer 10 is wider than those, 32 and 30, located further away from this corner, and a suitable arrangement of the width and position of the slats will enable the balance of air across the mixer 10 to be equalled out with a fair amount of efficiency.

Throttling of the current of air at the pointed corners of the mixing device 10 may also be achieved by means of perforated plates having a greater or smaller proportion of holes, as illustrated in the right-hand section of Figure 4. As is apparent from the Figure, the plate designated 36 has fewer holes than that designated 38 which is located further towards the middle of the mixer 10, i.e. covers channels of greater length, while those channels lying even further in towards the centre of the mixer 10 remain entirely without throttling devices. With the help of the perforated plates 36, 38, the air flowing through the mixing device can be adjusted and balanced with a high degree of accuracy.

A further means of equalizing the currents flowing through the mixing device is to provide the mixer with a pressure-compensating device as shown in Figures 5 and 6. The pressure-compensating device 40 illustrated in Figure 5 is manufactured of the same material as the body of the mixing device 10 and consists of layers of single-faced corrugated units stacked on top of each other, preferably with all the corrugation layers parallel. The pressure-compensating device 40 hence has straight channels running from the short side D of the device 40, parallel to the other shot side E, to the diagonal side F which joins one of the inlet sides of the mixer device 10, hence allowing the channels of the pressure-compensating device 40 to communicate with those of the mixer device 10. The corrugation height and length *l* of the edge of the pressure compensating device 40 should be so adapted as to ensure that the pressure drop in the medium will be of approximately the same magnitude as the medium passes through the longest channels of the pressure-compensating device and the mixer respectively. The pressure-compensating devices illustrated in Figure 5 may, like the mixing devic , be produced from a diag nally divided square r rectangular b dy. Figure 6 illustrates an example of a cas in which adaptation of the pressure-compensating device 40a to the drop of pressure ccurring in the mixing device has led t an irregular shape in the former.

The pressure-compensating devices 40, 40a illus-

trated in Figures 5 and 6 produce a uniformly distribut d fl w to ach channel in the mixing devices 10, 10a and may therefore b used when requirem nts as to accurate mixing are high, while the version using throttling slats 30, 32, 34 or plates 36, 38 as illustrated in Figure 4 is better used when demands as to the uniformity of the mix are moderate.

A further method of equalizing the flow across the discharge area of the mixing device is to design the mixer such that the channels will be of equal length. An embodiment of this nature is shown in Figures 7a-7c, in which the mixer 10b is mounted by the usual means in the two ducts or shafts 20, 22 carrying the media to be mixed and the duct or shaft 24 conveying the mixed media away from the mixer in the direction of the arrows in the drawing. The mixer 10b illustrated in Figure 7a hence has straight, parallel channels 44 running from the inlet faces of the mixer 10b adjoining the ducts 20, 22 parallel to their respective outer wall of the mixer 10b to the outlet area discharging into the duct designated 24. Since the mixing device 10b, like those described in the preceding paragraphs, is built up of layers of single-faced corrugated units, such layers alternately adjoining each of the ducts 20 and 22 respectively and hence allowing the medium from either of these to flow only through every other channel of the mixer as seen vertically, the inlet to the intermediate layer must be sealed, as illustrated at 46 in Figure 7b. Sealing 46 can be provided at manufacture through an appropriate design of the corrugated units or by welding or gluing a separate strip into position.

The mixing device may clearly be so constructed, in this and previous embodiments, as to be fitted in round shafts, in which case the shape of the device will be round, as in the mixing device 10c illustrated in Figure 7c.

The mixing device can naturally also be constructed so as to be able to mix three or more media, as shown in the embodiment illustrated in Figures 8a and 8b. The mixing device 10d of Figure 8a is connected not only to shafts 20 and 22 but also to an intermediate shaft, designated 48 in the Figure. The mixer 10d illustrated in Figure 8a therefore comprises at least three layers of stacked, single-faced corrugated units, the middle layer leading from the shaft designated 48 to the outlet shaft 24 having a rectangular shape and channels running parallel to its longer sides, while the layers leading from shaft 20 and 22 respectively to the common outlet shaft 24 have channels running parallel to the oblique sides of the mixing device. Since the medium from each of the inlet shafts 20, 22, 48 can only pass through one in three of the layers leading to the common outlet shaft 24, the inlet to the two intermediate layers must be sealed, as shown at 46 in Figure 8b, in the same manner as described for Figures 7a and 7b. The mixing devices 10b, 10c, 10d illustrated in Figures 7a-7c and 8a, 8b, are thus built up of layers of single-faced c rrugated sheets stacked up n ach ther, and preferably with all th corrugated layers carrying ne medium placed at an angle to all the other layers. A medium flowing through the unit will thus be intimately mixed with the other media at the outlet leading to the common shaft designated 24. It is therefor important that the fl w of m dia is correctly adjusted in each of th shafts. If the first and last corrugated layers are given the same corrugation h ight as the others, the flow through the said layers will be excessive and mixing will be uneven at each of these sides of the mixer. A suitable means of counteracting this is to lower the corrugation height of the first and last corrugated unit or layer, preferably giving them half or slightly more than half of the normal corrugation height as illustrated in the Figure by the layer designated 50, which may be compared with the corrugation height of the intermediate layers or channels designated 44 in Figures 7b and 8b.

In the embodiments of the mixing device illustrated in Figures 7a-7c and 8a, 8b, the speed of the media in the outlet shaft 24 immediately after the mixer is greater than in the shafts 20, 22, 48 before the mixer. In the embodiment of the mixing device 10b illustrated in Figure 7a for example, the speed of the media in the outlet shaft 24 is proportional to the sum of the speeds of the two media flowing through the supply shafts 20, 22, which, in many cases, is a disadvantage.

A method of eliminating this disadvantage is to make the corrugations increasingly high and/or widen the distance between the tops of the corrugations as they run from the inlet to the outlet, or alternatively to provide an increasingly large distance between the corrugations but keep the corrugation height constant, again as looking towards the outlet. Corrugated sheets of this nature can be fabricated between more or less conical rollers, which are able to produce corrugated sheets having increasingly high corrugations and a widening distance between the corrugated tops. By displacing one of the conical corrugation rollers in relation to the other in a suitable fashion it is also possible to produce corrugated sheets of constant corrugation height but with a widening gap between the corrugations themselves. A further method of manufacturing such sheets is, once a sheet has been produced between conical, corrugated rollers and given increasingly high corrugations at an increasingly wide distance from one another, to continue treatment by pressing the sheets to reduce the corrugation height to the desired level. Figures 9-11 show an example of a sheet 52 having conical corrugations the tops of which, as measured by D in Figures 10 and 11 respectively, are closer at one end of the sheet 52 than the other while the corrugation height H remains the same. The end of the sheet 52 where the tops are closest is thus mounted in one of the ducts, 20 or 22, supplying the media to be mixed, the end where the tops are widest apart being mounted in the discharge duct 24 as illustrated in Figure 12, which shows an embodiment of a mixing device 10e built up of layers 52 of conical, single-faced corrugat d units f th type shown in Figure 9.

Regulating devices, illustrated in Figure 13, may be provided in the supply ducts 20, 22 before the mixing device 10 for the purp se of regulating th proportion of the two media to be mixed. In the embodiment illustrated in the Figure these take th form of mov able plates 54 in which ar cut slots 56

f a shape quivalent to the inlet of each layer f the mixing device 10. Since th slots 56 can be mad t coincide with th open channels 44 of the mixing device 10 to a greater or lesser degree, the mix proportion of the media flowing from the corresponding inlet duct or shaft 20, 22 can be regulated, as is apparent from Figure 13. This regulator may also take the form of a throttle or similar device of the type used for mixing gases or else may be of a design similar to the regulating valves used for liquids.

A further means of regulating the mix proportion of the media is to connect two mixing devices 10b, of the type shown in Figure 7a for example, in series and to make one of the mixing devices moveable in relation to the other, as illustrated in Figure 14a, in which the upper mixer 10b is moveable in relation to the lower mixer 10b. An arrangement of this nature is suitable, for example, for mixing three media and when it is desirable to be able to vary the proportions of the two media being mixed with a third. The moveable mixing device should be displaceable in a direction perpendicular to the plane of the channels or single-faced corrugated layers. In one of the two end positions of such moveable mixing device, illustrated in Figure 14, the channels are open and allow the medium from supply duct 20 to flow through the series-connected device. The media arriving from duct 20 and 22 are hereby mixed, the latter leading direct to the fixed, lower mixer 10b and adjoining it at the outlet to the common discharge shaft 24. As the upper mixing device 10b is displaced, movement taking place in a vertical direction relative to the device, i.e. perpendicular to the plan view afforded by the drawing and indicated by the arrow in Figure 14b, the channels are increasingly closed to the medium flowing in from the duct designated 20 and increasingly opened to that supplied by the duct designated 48, meaning that mixing of the media supplied by each of the ducts 20, 48 and 22 will take place when the device is set at its intermediary positions. The moveable mixing device 10b therefore functions on the same principles as the moveable slotted plates 54 illustrated in Figure 13, except that besides shutting off the supply from one of the shafts, 20 or 48, the moveable mixing device of Figures 14a and 14b also opens the supply of medium arriving from the other shaft, 48 or 20. When the moveable mixing device is set at its other end position the channels are fully open to the medium supplied by shaft 48 but closed to that of shaft 20, meaning that mixing now takes place of the media arriving from shaft 48 and shaft 22. In the embodiment described in the present the medium supplied by the shaft designated 22 is always a component of the resulting mixture discharged into the shaft designated 24, the proportion of the admixture from shafts 20 and 48 respectively being variable between nought and one hundred perc nt.

Fr m th ab ve it is appar nt that a mixing device has been achiev d in which the pressure drop ver th mixing devic is substantially low r than in th mixers used hithert ; and it also r quires far less space than ther devices hitherto available. Als , less mat rial is required for construction of the d vice, and furthermore the mat rial us d may be thin since the several layers of the device provide effectiv mutual support. A pr tective h using (not illustrated) may b pr vided round the d vice in order to improve convenience of handling, and corner fixtures 42, shown in the Figures, may be used to help mount the mixer in the duct system.

As regards temperature equalization, the present device performs excellently in mixing two media at different temperatures. The mixing device of the invention is also extremely useful in continuous chemical processes incorporating a mixing or reaction stage. Mixing is achieved very rapidly by the device at a mixing stage. Efficient mixing shortens the diffusion path of the reagents, and the reaction as a whole is consequently speeded up, giving increased production per unit of time. In the case of instantaneous reactions at reaction stages, the speed with which mixing can be carried out is critical for product flow. The rapid, intimate mixing obtained in the device of the invention permits a high level of continuous production but requires only a small reaction volume. In rapid reactions, mixing and the reaction itself take place simultaneously, with a resulting rise or fall in temperature. The efficient mixing achieved by the device ensures an even temperature in the media without zones of temperature below or above the required level.

The invention is evidently not limited to the embodiments shown in the present but may be modified and varied within the terms of the claims to follow. Thus, it is clear that the mixer 10, 10a need not be oriented as illustrated in the Figures but may be constructed with the single-faced corrugated layers standing or in some other position relative to the horizontal plane. Similarly, the angle between the channels of the adjacent single-faced corrugated layers need of course not be a right angle but will vary with the shape of the mixing device. It is naturally also conceivable to use the mixer for mixing more than two media, in which case a number of inlet faces may be provided from which run straight channels so arranged as to discharge evenly over the face of a common outlet side. In addition, in view of the available pressure drop and variations occurring in the flow, etc., it may be of advantage to provide the channels running in one direction with a greater corrugation height than that of those running in the other direction.

CLAIMS

1. A mixing device for mixing flowing media, such as gases, liquids, etc., in which the media are introduced into a mixing device separately and are mixed as they flow out of it, the mixing device comprising at least two systems of separate through channels which each runs from its respective inlet surface, extends towards and discharges from a common outlet face of the mixing device, such channels running at an angl to on anoth r such that the media fl wing from the two or m re inlet faces are essentially evenly distribut d ov r the surface f the utlet fac .

2. A device acc rding t claim 1 wherein the mixing device comprises at least two layers of single-faced corrugation being plan and corrugated sheets

arranged in contact with each oth r.

3. A device according to claim 2 wherein the single-fac d corrugated layers are arranged such that the corrugations f the corrugated sheets are arranged at an angle to each other in adjacent layers.

4. A device according to claim 1, 2 or 3 wherein the mixing device in plan view, has a three-sided, preferably triangular shape, two of the sides of such triangle forming the inlet faces and the third forming the common outlet face.

5. A device according to claim 4 wherein the channels of the three-sided mixing device have corrugations of different heights running from the inlet faces for accommodation to supply currents of different volumes.

6. A device according to claim 4 wherein the shorter sides of the three-sided mixing device are of different lengths for accommodation to supply currents of different volumes.

7. A device according to claim 4, 5 or 6 wherein throttling devices are located at the corners of the three-sided or triangular mixing device joining the common discharge face in order to equalize or balance the media flow over the body of the mixing device.

8. A device according to claim 7 wherein the throttling devices are in the form of slats covering a determined number of channel openings on the inlet surfaces of the mixing device; and in that the area covered by the slats increases in a direction towards the said corners of the mixing device.

9. A device according to claim 7 wherein the throttling devices are in the form of perforated plates arranged across the inlet surfaces of the mixing device; and in that the plates are progressively less perforated in a direction towards the said corners of the mixing device.

10. A device according to claim 4, 5 or 6 wherein compensating devices having straight, mutually parallel channels are connected to the inlet faces of the mixing device, each such compensating device having a form such that, in combination with the channels of the mixing device, passages are formed producing essentially the same pressure drop irrespective of the position of such passages relative to the mixing device.

11. A device according to any of claims 1-10 wherein the mixing device comprises several systems of channels so formed that the channels are of equal length in every layer.

12. A device according to any of claims 1-11 wherein the channels of the mixing device afford a smaller area for the passage of a medium.

13. A device according to any of claims 1-12 wherein the mixing device comprises a system of conical channels affording an increasingly large area for the passage of a medium in the direction of flow.

14. A device according to any f claims 1-13 wh rein the mixing device is provided with regulating devices mount d bef re the inlet faces of the mixing device for regulating the amounts of the media flowing into the devic .

15. A device according to any f claims 1-14 wherein at least tw mixing d vices are connected in series and that ne f these is displaceabl by an am unt equivalent to the width of at least one channel r lative to the other in such manner that the prop rti n f two media to be mixed in at least a third medium can be varied.

16. A method of mixing two fluid media comprising the steps of passing a first fluid media through a first plurality of channels extending from a respective inlet to a common outlet in a mixing device, passing the second fluid media through a second plurality of channels extending from a respective inlet to the common outlet in the mixing device, and arranging the respective channels for the media so that the media are mixed as they flow out of the mixing device at the common outlet.

17. A mixing device as hereinbefore described with reference to and as illustrated in the accompanying drawings.

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